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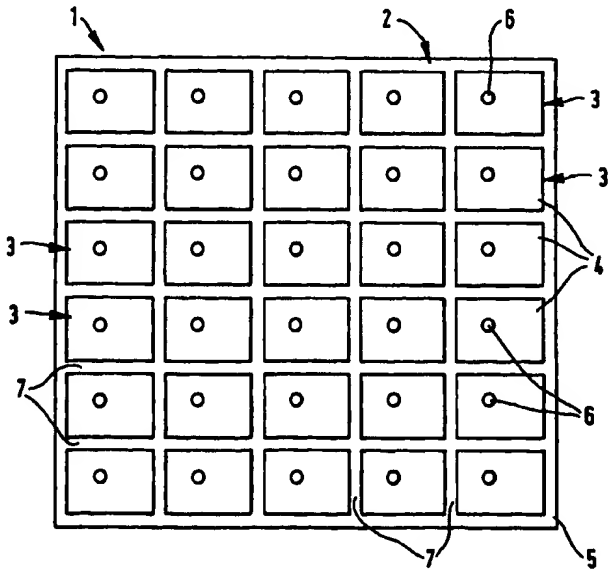

(57) Abstract

Acoustic apparatus comprising an array of loudspeakers characterised in that the loudspeakers comprise resonant panel–form members having vibration exciters associated therewith to apply bending wave energy to the panel–form members to cause them to resonate to produce an acoustic output and in that the panel–form loudspeakers are proximately arranged to produce substantially uncorrelated acoustic outputs and overall acoustic output substantially as though a single acoustic source.

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TITLE: AN ACOUSTIC OBJECT

DESCRIPTION

TECHNICAL FIELD

The invention relates to an acoustic object or apparatus comprising an array of loudspeakers. Preferably, but not exclusively, the invention relates to an acoustic object comprising an array of panel-form loudspeakers of the kind described in our International patent application WO97/09842.

BACKGROUND ART

It is known to provide arrays of conventional pistonic loudspeakers reproducing the same signal for the purpose of sound reinforcement. A disadvantage of such an array is that due to the coherent phase of such speakers, interference occurs between the acoustic output of the various speakers of the array to cause destructive lobing

effects.

We have proposed in our International patent application WO97/09853 to provide a multi-channel distributed mode loudspeaker arrangement comprising a large centre panel loudspeaker which acts as a projection screen and smaller left and right hand panel loudspeakers. In such a three channel system, the channels normally reproduce different signals, namely left and right hand stereo signals and a centre channel signal and this invention can be seen as arising from the surprising results of first putting a mono signal to such a speaker arrangement, particularly appreciating the one-source rather than three-source nature of reproduced sound.

DISCLOSURE OF INVENTION

According to the present invention there is provided acoustic apparatus comprising an array of loudspeakers, characterised in that the loudspeakers are panel-form proximately arranged for common drive to produce acoustic outputs substantially uncorrelated in phase and effectively operating substantially as a single acoustic source. Such an array can be viewed as at least mainly constructively additive as to individual acoustic outputs of its constituent loudspeakers, in effect substantially or to a large extent free of destructive interference.

The loudspeakers will be suitably proximate where there is no mechanical coupling between edge vibration of adjacent panels, say, down to 1mm or less where such edges are not constrained against vibration; and up to where

there is only acceptable leakage between adjacent panels, which is frequency dependent and can be affected by such as provision of inert baffle means, say not usually more than dimensions of the panel(s) concerned at least for embodiments to be described. Overall requirement is operation substantially as though the whole array is a single acoustic source.

The loudspeakers may be of the same size and shape, or of different sizes of essentially similar shapes, or of the same or different sizes of the same or different shapes, say to make up whatever effectively "tiled" arrangement may be desired. Thus the array may be of any shape and may preferably have four or more loudspeakers that can be in more than one row. The panel-form loudspeakers may be inter-connected between their adjacent edges. The inter-connections between the panels may include hinges.

A flexible member may be arranged to overlie at least the margin of each panel and to be attached thereto to form the inter-connection between the panels. The flexible member may be a sheet which may overlie a face of each panel to form a substrate and which may form the hinges. The flexible member or sheet may be printed with an electrical circuit whereby the panels can be electrically connected. A single pair of electrical terminals on the substrate may be electrically connected to each of the vibration exciters of the loudspeakers.

Frame means may be provided to connect the edges of the panels together. The frame means may comprise an

acoustic baffle.

The panels are preferably resonant distributed mode loudspeakers in which each loudspeaker comprises a member having capability to sustain and propagate input vibrational energy by bending waves in at least one operative area extending transversely of thickness to have resonant mode vibration components distributed over said at least one area and have predetermined preferential locations or sites within said area for vibration exciter means and having a vibration exciter mounted on said member at one of said locations or sites to vibrate the member to cause it to resonate forming an acoustic radiator which provides an acoustic output when resonating.

It can be shown that an array of distributed mode loudspeaker panels reproducing the same audio signal produce a resultant acoustic field that closely approximates the summation of the individual power responses of each distributed mode loudspeaker. Due to the diffuse nature of the acoustic radiation from a distributed mode loudspeaker, such an array does not exhibit destructive interference.

Formed as an array of "tiles", distributed mode loudspeaker panels may be used in an installed form, e.g. on a substrate such as a wall or assembled onto a thin flexible carrier that will allow it to become easily foldable and hence portable for professional or similar applications. A thin and light thermoplastic sheet material such as that known under the Trade Name "Melinex",

acoustically transparent textiles fabric or other material may be used to connect the individual panels in a 'tiled' array, and to create flexible joints between panels.

The array of distributed mode loudspeakers permits increased power handling by virtue of higher dissipation in multiple exciters. This arrangement may also be utilised to increase the maximum sound pressure level attainable from the distributed mode loudspeaker system.

Since the array of loudspeaker panels may be flexible at the panel boundaries, it may be wrapped around columns or other architectural features physically to conform to various structural profiles and contours.

In some applications, such as a home cinema screen, the panel array allows space saving by permitting the acoustic object to be rolled up into a manageable size for storage and/or transportation.

Directional control may be exercised by selecting distributed mode loudspeakers with a variety of surface geometry specifications. Alternatively, or in addition, electronic delay in the applied signal may be selectively applied to the individual panels in order to shape and control the directivity of the acoustic output of the system. Additionally the array distribution may itself be used to control the acoustic distribution and directivity.

Further control of the radiation pattern may be provided by a zigzag folding arrangement of the panels. This allows the physical size of the unfolded speaker system to be finely adjusted according to application and

the required acoustic property by choosing the degree of unfolding and consequently the included angle between the folds.

Other constants defining acoustic performance include the equations relating the distribution and placement of the panels in the array, e.g. geometric, and including semi random relationships which will further aid the diffuse performance of the array.

In certain realisations where flexible thermoplastic sheet material or film is used as a "tiling" attachment or as a backing, conductive electrical tracks may be printed onto the film to facilitate electrical connections between the individual panels. This has the advantage of tidy and reliable electrical wiring for the "tiled" array. The defined connection pattern also enables a finely graded control of three parameters namely sensitivity, load impedance, and power handling capacity.

In another form, a panel array may be realised by appropriately hinged frames e.g. of plastics, each supporting a panel. This may be a more costly approach to 'tiling' onto a flexible sheet but may be better suited to certain applications. The benefits may include superior low frequency performance and sound quality resulting from assemblies with greater mass, and the potential for more substantial mouldings to provide a beneficial acoustic baffling effect.

BRIEF DESCRIPTION OF DRAWINGS

The invention is diagrammatically illustrated, by way

of example, in the accompanying drawings, in which:-

Figures 1 and 1a comprise respective front and side views of an array of panel-form loudspeakers in accordance with the invention;

Figure 2 is a side view similar to that of Figure 1a of an array contoured to form an arc;

Figure 3 is a side view similar to that of Figure 2, of a zig-zag contoured array, and

Figure 4 is a rear view of a typical series/ parallel printed circuit track pattern for connecting and energising the exciters of the respective panels in the array.

BEST MODES FOR CARRYING OUT THE INVENTION

In the drawings there is shown an acoustic object (1) in the form of an array (2) of generally identical panel-form loudspeakers (3) mounted in several rows on a substrate (5). In this embodiment the panel-form loudspeakers are resonant panel loudspeakers of the kind described in International patent application WO97/09842. Thus each loudspeaker (3) comprises a resonant panel (4) on which is mounted a vibration exciter (6), which may, for example, be an inertial electrodynamic device, to apply bending wave energy to the panel to cause it to resonate to produce an acoustic output.

The substrate is a flexible sheet, e.g. of plastics film which is fixed, e.g. by adhesive means to one face of each panel whereby the panels are retained in mutually adjacent relationship to form six rows of five panels in a rectangular array. The arrangement is such that thin

strips of the substrate are defined between the edges of adjacent panels which strips form hinges (7) whereby the array can be disposed in a planar condition as shown in Figure 1a or can be folded for storage or contoured as indicated in Figure 2 into an arcuate shape. Alternatively, the array may be arranged in a zig-zag formation as indicated in Figure 3.

As shown in Figure 4, the other face of the substrate may be formed, e.g. by printing, with electrically conductive tracks (8 and 13) respectively, with intermediate tracks arranged in series/parallel, shown parallel along the rows relative to respective pairs of positive and negative contacts (9,10) for respective terminals (not shown) of the vibration exciters (6), and series across the rows, provided with respective pairs of positive and negative contacts (9,10) respectively for connecting to the respective terminals (not shown) of the vibration exciters (6), whereby the exciters can be energised in convenient manner, the conductive tracks (8,13) having respective input terminals (11,12).

It will be understood that while embodiment of the invention has been described in relation to a rectangular loudspeaker array having a flexible substrate forming the foundation for the loudspeaker panel array, it would be possible to associate the loudspeaker panels of the array in other ways. Thus the panels might each be mounted individually in frames arranged for connection one with another, and/or two or more panels might be mounted in a

common frame. The frame interconnections might be hinged. Alternatively the loudspeaker panels might be mounted in or on a substrate that might be rigid or semi-rigid or of desired compliance, and which might form a baffle. However, any operatively effective proximate association of two or more panel-form loudspeakers is envisaged, including free of specific physical inter-connection provision, i.e. located in any way conducive to desired operation. Different sizes of panels might be as replacement(s) in Figure 1, for sub-array(s) of adjacent loudspeaker units by single larger unit(s). Different shapes of panels include elliptical, super-elliptical etc. and may be mixed for any desired array shape.

INDUSTRIAL APPLICABILITY

The invention as shown in the drawings thus provides or facilitates:-

1. increased power handling for high power applications;
2. interleaving of distributed mode loudspeaker frequency distribution by chosen offset of the modal distribution of the individual panels;
3. better control of off-axis uniformity by the choice of the orientation of the various distributed mode loudspeaker panels;
4. control of directivity by overall surface geometry of the panel array, e.g. curvature, whether simple or complex;
5. use of digital signal processing for control of directivity by control of differential delay to

individual panels in the array;

6. use in projection applications by physically separating the panel array and the optically reflective surface onto which the video or image is projected, to facilitate portability by rolling up both parts of the apparatus as an object, namely the 'tiled' array and the screen, and

7. tailoring of overall acoustic response by introducing electronic delay and or transfer function equalisation through analogue or digital methods.

An acoustic object of the invention may find application in automobiles, e.g. as or in a car headliner.

The invention thus provides a simple and improved loudspeaker array.

CLAIMS

1. Acoustic apparatus comprising an array of loudspeakers characterised in that the loudspeakers comprise resonant panel-form members having vibration exciters associated therewith to apply bending wave energy to the panel-form members to cause them to resonate to produce an acoustic output and in that the panel-form loudspeakers are proximately arranged and have common drive to produce substantially uncorrelated acoustic output and overall acoustic output substantially as though a single source.

2. Acoustic apparatus according to claim 1, wherein the panel-form loudspeakers are all of the same size.

3. Acoustic apparatus according to claim 1 or claim 2, characterised in that the panel-form loudspeakers are inter-connected between their adjacent edges.

4. Acoustic apparatus according to claim 3, characterised in that the inter-connections between the panels include hinges.

5. Acoustic apparatus according to any preceding claim, characterised by substrate means on which the array of loudspeakers is mounted.

6. Acoustic apparatus according to any one of claims 4 to 5, characterised by a flexible member overlying at least a marginal portion of each panel and attached thereto to form the inter-connection between the panels.

7. Acoustic apparatus according to claim 6 when dependent on claim 4, characterised in that the flexible member also forms the hinges.

8. Acoustic apparatus according to any one of claims 5 to 7, characterised in that the flexible member forms the substrate.

9. Acoustic apparatus according to any preceding claim, characterised by a single pair of input terminals to which the vibration exciters on each loudspeaker in the array are electrically connected.

10. Acoustic apparatus according to claim 9, wherein the input terminals are on the substrate.

11. Acoustic apparatus according to any one of claims 6 to 10, characterised in that the flexible member is printed with at least one electrical circuit whereby the vibration exciters can be electrically energised.

12. Acoustic apparatus according to any one of claims 6 to 11, characterised in that the flexible member is a sheet arranged to overlie a face of each panel in the array.

13. Acoustic apparatus according to any preceding claim, characterised by frame means connecting the edges of the panels together.

14. Acoustic apparatus according to claim 13, characterised in that the frame means comprises an acoustic baffle.

15. Acoustic apparatus according to any preceding claim, characterised in that the panels are resonant distributed mode loudspeakers.

16. Acoustic apparatus according to any preceding claim, characterised in that the array comprises more than one row of the panel-form loudspeakers.

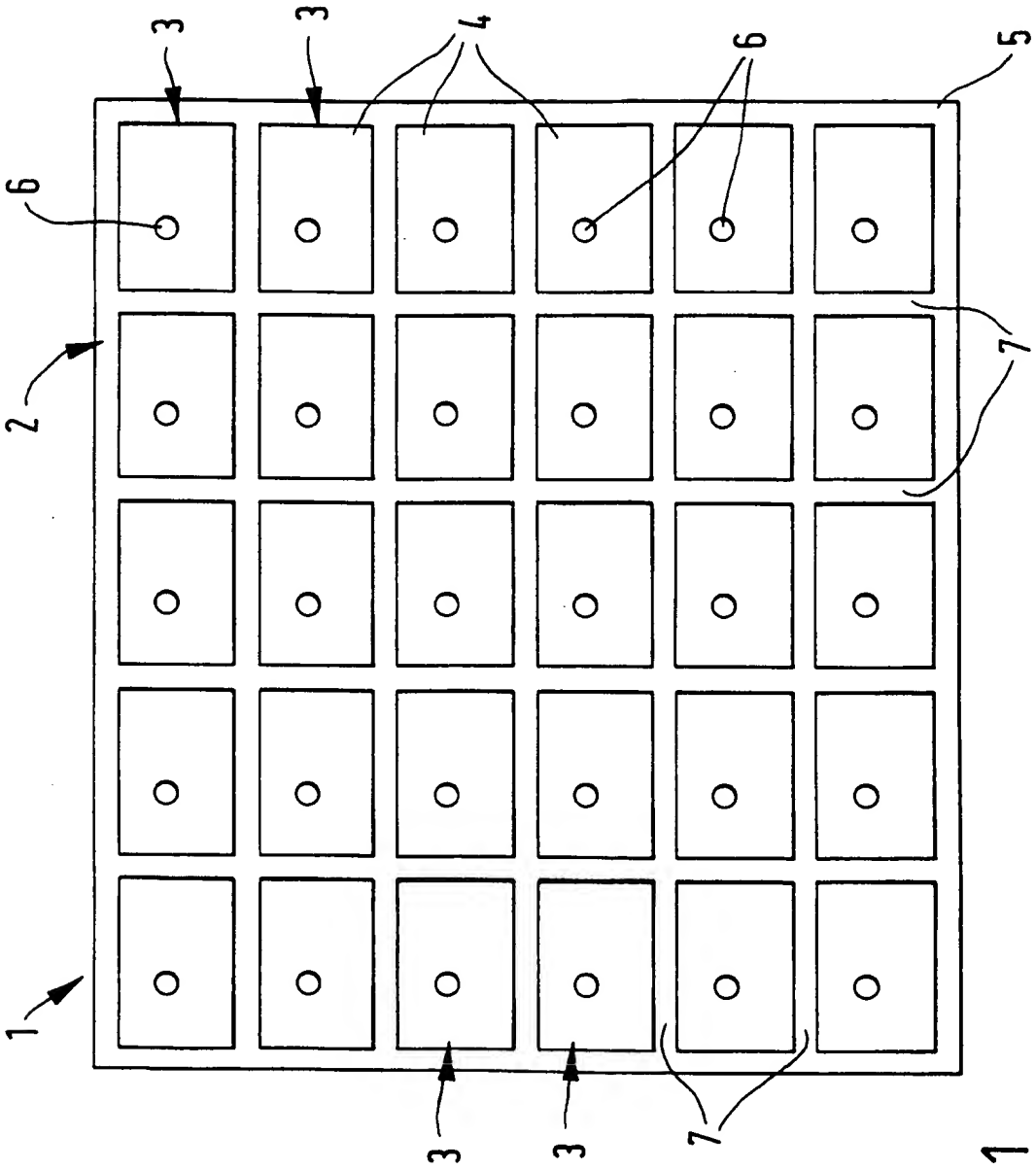

FIG.1

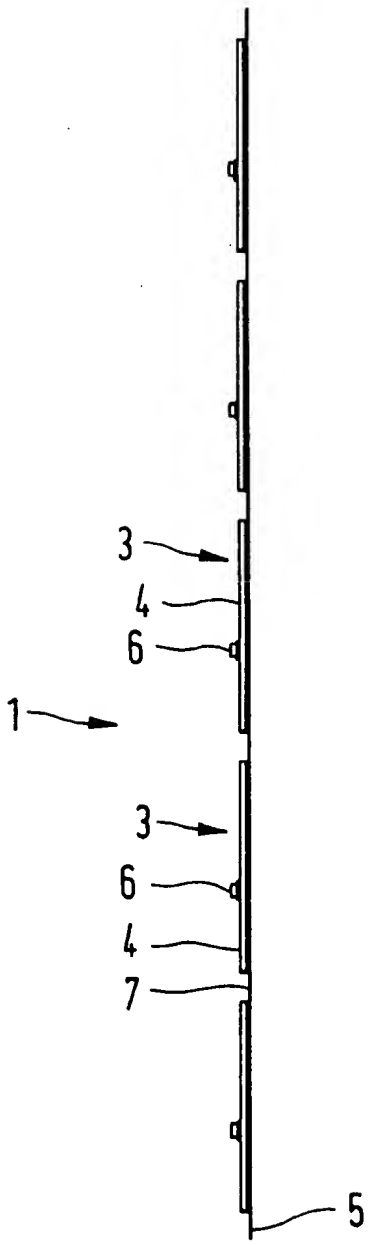

FIG.1a

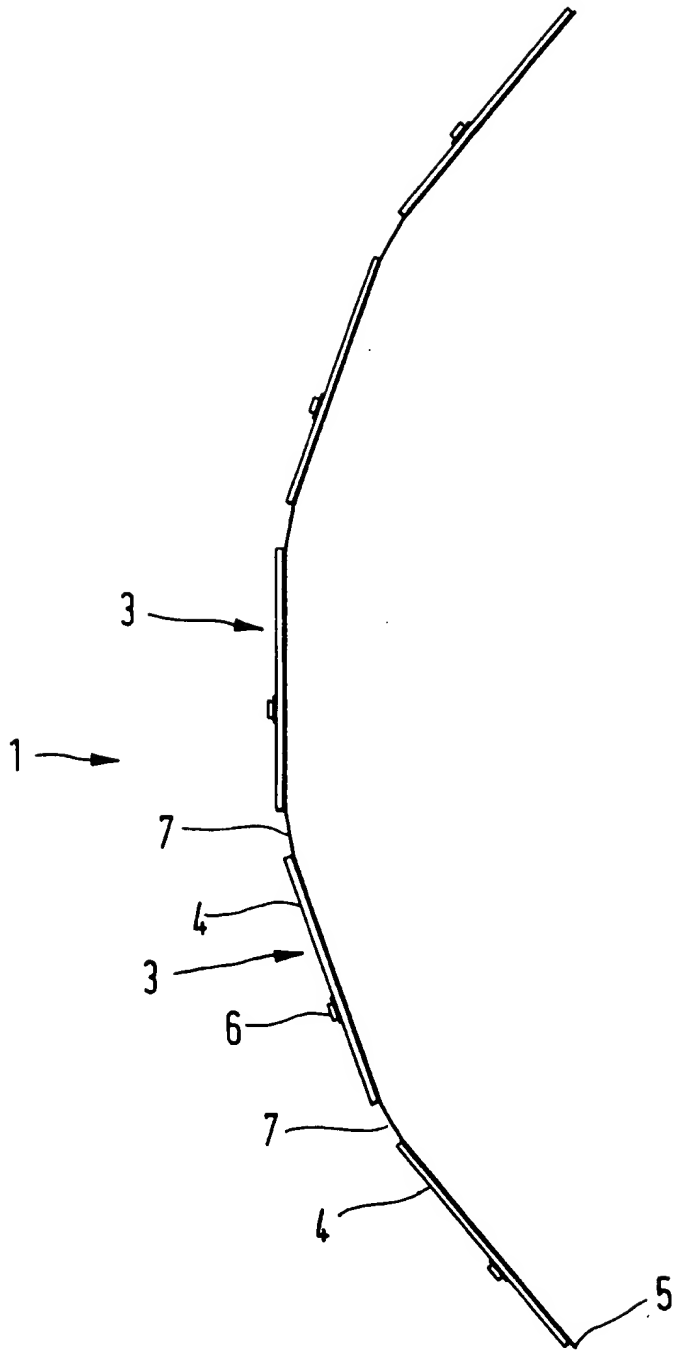

FIG.2

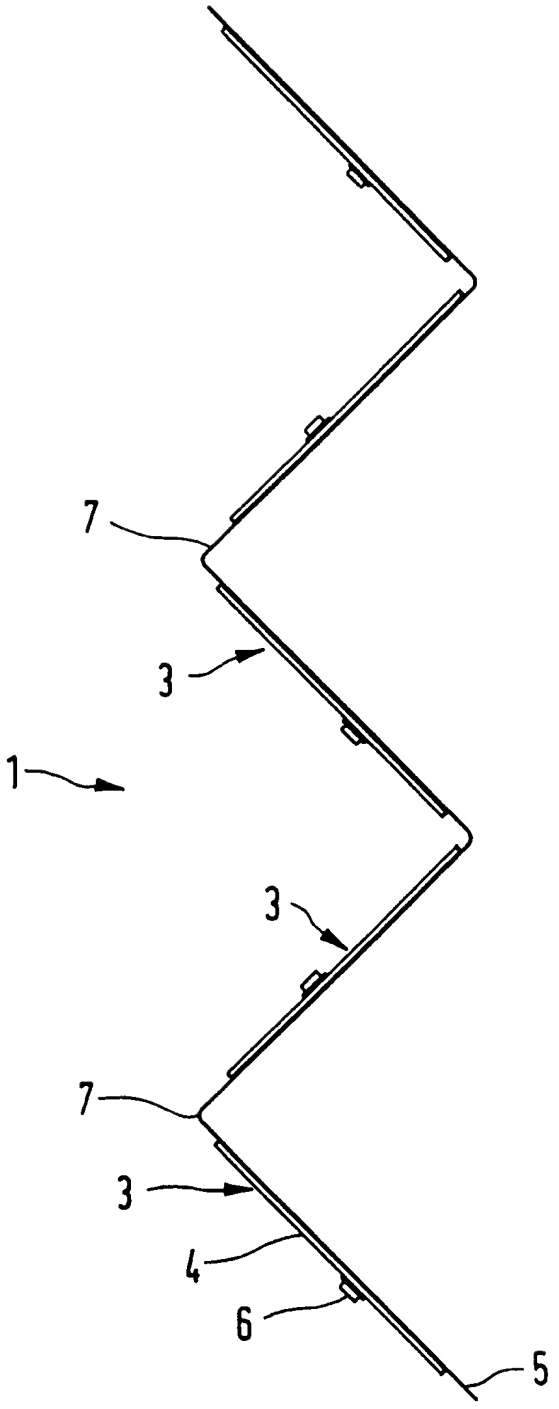

FIG. 3

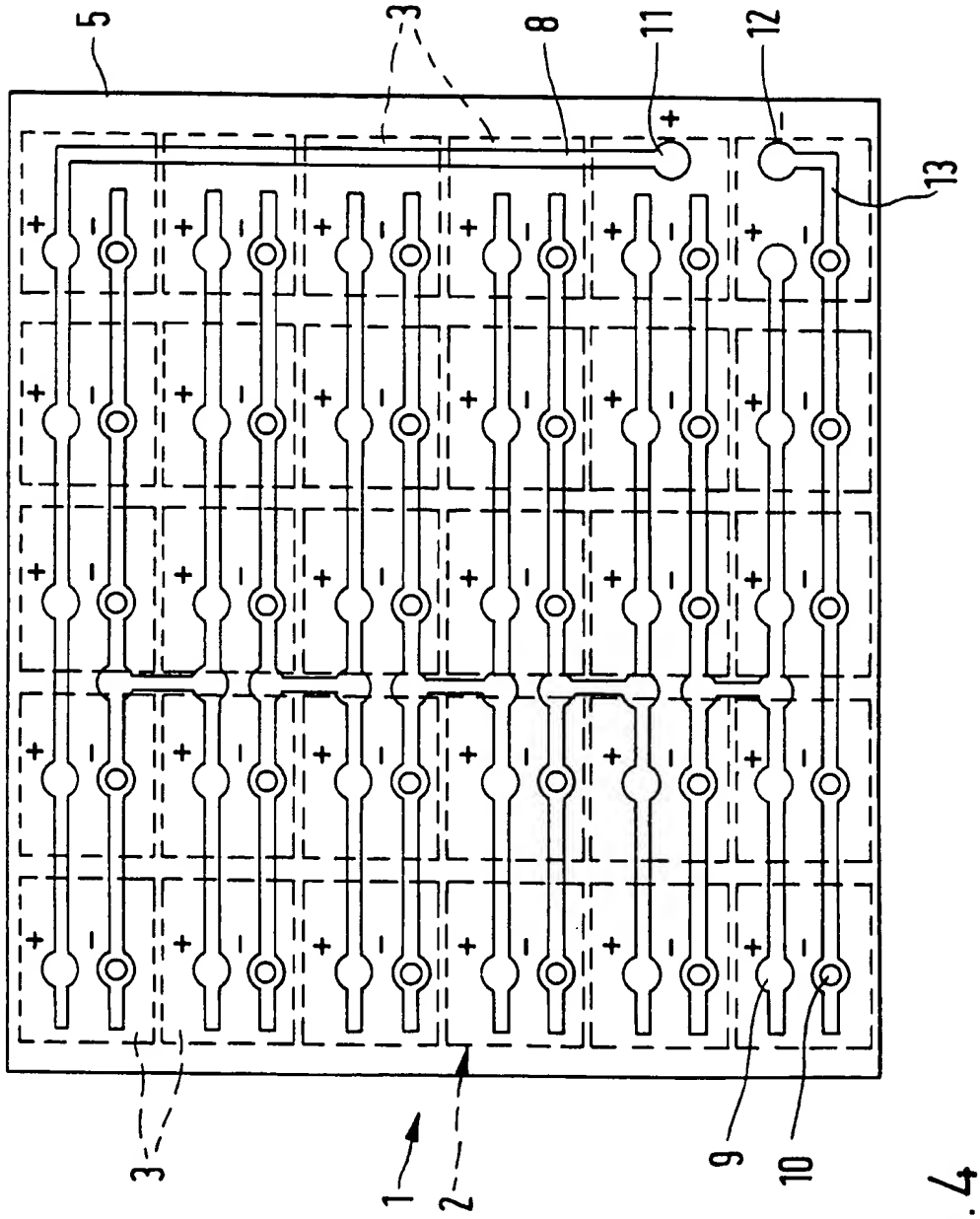

FIG. 4